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Guidance on the Safe Operation of Vacuum Insulated Storage Tanks.

VIEs and VITs.

Applicable to the UK and Ireland
April 2009

Contents

1 Introduction and Background

2 Tank Design and Operation

3 Automatic Economisation

4 General Housekeeping Guidance

5 Daily Check Regime

Introduction

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Following an incident in the UK where a cryogenic storage tank suffered a failure of the outer jacket, it is imperative that users/operators of Vacuum Insulated Storage tanks are fully briefed on indications of a potential problem so as to be able to take the appropriate action. The failed component was part of the internal automatic economiser system.

Many users of such storage equipment lease their tanks from the gas supplier and the maintenance of the pressure system is managed by that gas company. However, for the gas company to respond efficiently it needs to be advised of any significant changes as soon as possible

For users of BOC equipment the telephone number to report such incidents/changes is:-

0800 222 888

This number is manned 24hrs per day 365 days per year

This presentation's aim is to provide

a basic understanding of storage tank design,

clarification of the design feature (economiser) that caused the problem and

a simple guide to allow end users to identify potential issues at an early stage

Background

The incident has been covered in a number of documents issued by the Enforcing Authority (HSE), the British Compressed Gases Association (BCGA) and the European Industrial Gases Association (EIGA)

UK documentation can be found at:

- http://www.hse.gov.uk/chemicals/cryogenicalert.htm
- http://www.bcga.co.uk/publications/L11.pdf

Follow the links below to navigate this presentation:

Basic tank design
Economiser circuitry
Indications/conditions that are evidence of an internal pipework leak
General housekeeping issues

Basic vessel design

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Liquefied gases such as Nitrogen, Argon and Oxygen are stored at temperatures down to -196 degrees Celsius.

Under normal ambient conditions of +15 degrees Celsius these products are gases but as part of the manufacturing and storage process they are cooled and liquefied.

To maintain the product at low temperatures the storage tanks are vacuum-insulated. An outer jacket is built around the inner pressure vessel. The interspace is evacuated and is normally filled with perlite, an inert mineral insulation material. This gives a very efficient insulation barrier between the cold product and the outside environment.

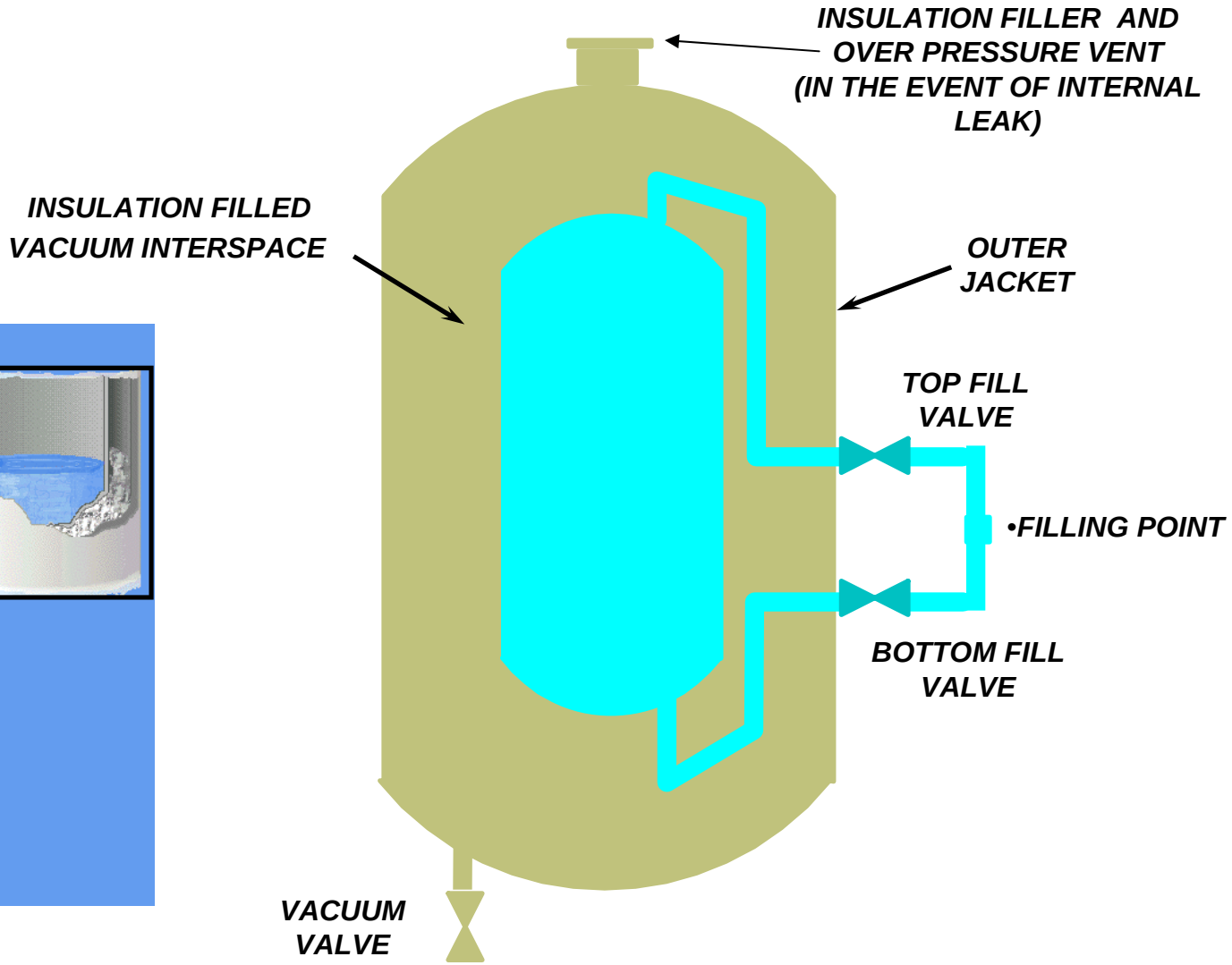
The insulation is so efficient that whilst the inner vessel is at -190C the outer jacket should be at ambient temperature under normal operating conditions. Pipework passes through this interspace to allow product to be filled and withdrawn and for pressure relief and instrumentation pipework to pass out. This does allow some heat in-leak.

Under normal operating conditions the tank pressure does not rise significantly. This is due to:

– Customer's demand lowering the liquid level which increases the gas space volume. If the increase in volume is greater than the "evaporation/boil off rate" then pressure does not rise

– At each fill any excess pressure can be reduced by the driver ensuring there is a sufficient flow of the new colder liquid through the top fill pipe.

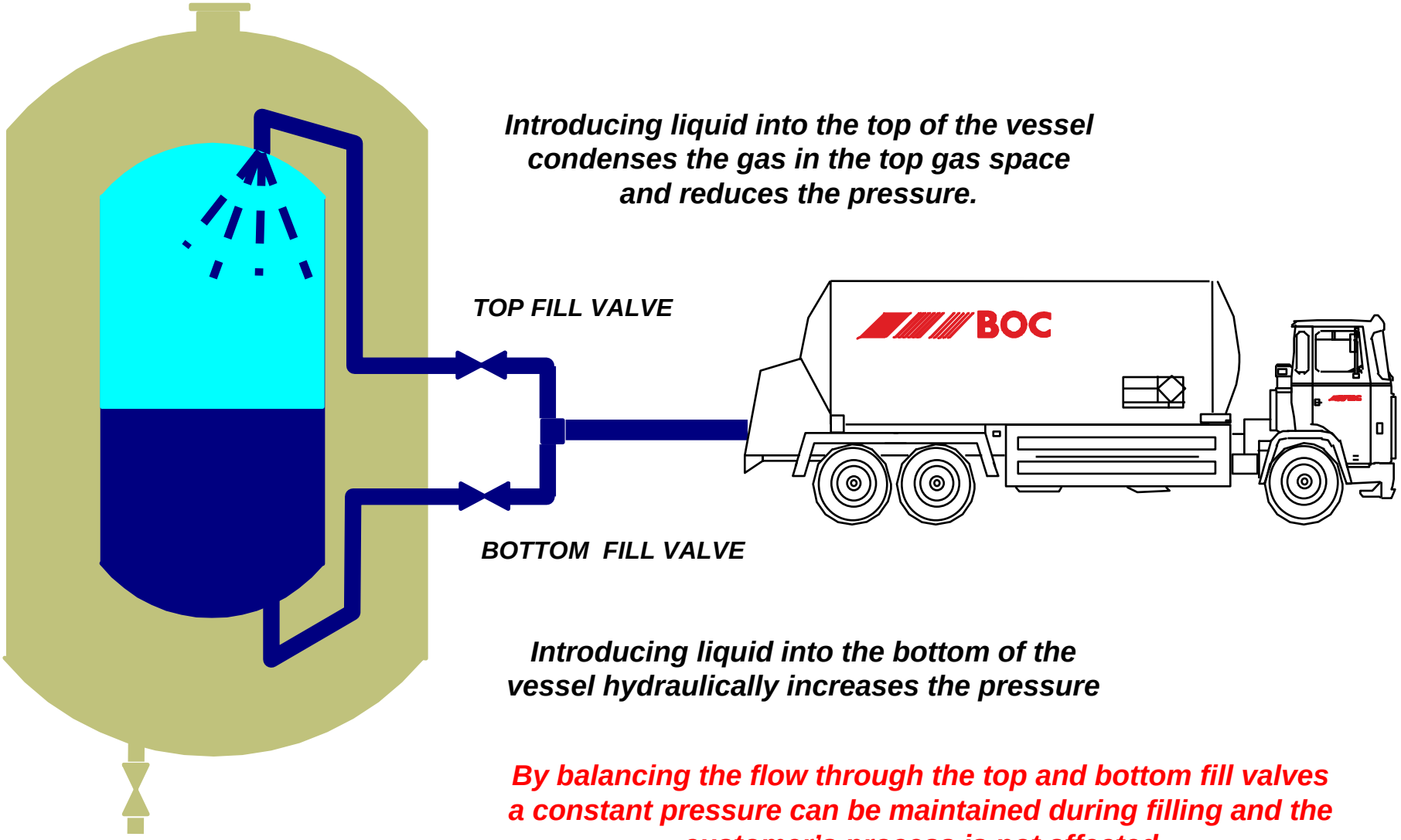
Basic tank design


INSULATION FILLER AND OVER PRESSURE VENT (IN THE EVENT OF INTERNAL LEAK)
INSULATION FILLED VACUUM INTERSPACE
OUTER JACKET
TOP FILL VALVE
•FILLING POINT
BOTTOM FILL VALVE
VACUUM VALVE

Cut away photograph

Depending on the size of vessel this interspace is approx 150-300mm

Filling



Introducing liquid into the top of the vessel condenses the gas in the top gas space and reduces the pressure.

Introducing liquid into the bottom of the vessel hydraulically increases the pressure

By balancing the flow through the top and bottom fill valves a constant pressure can be maintained during filling and the customer's process is not affected

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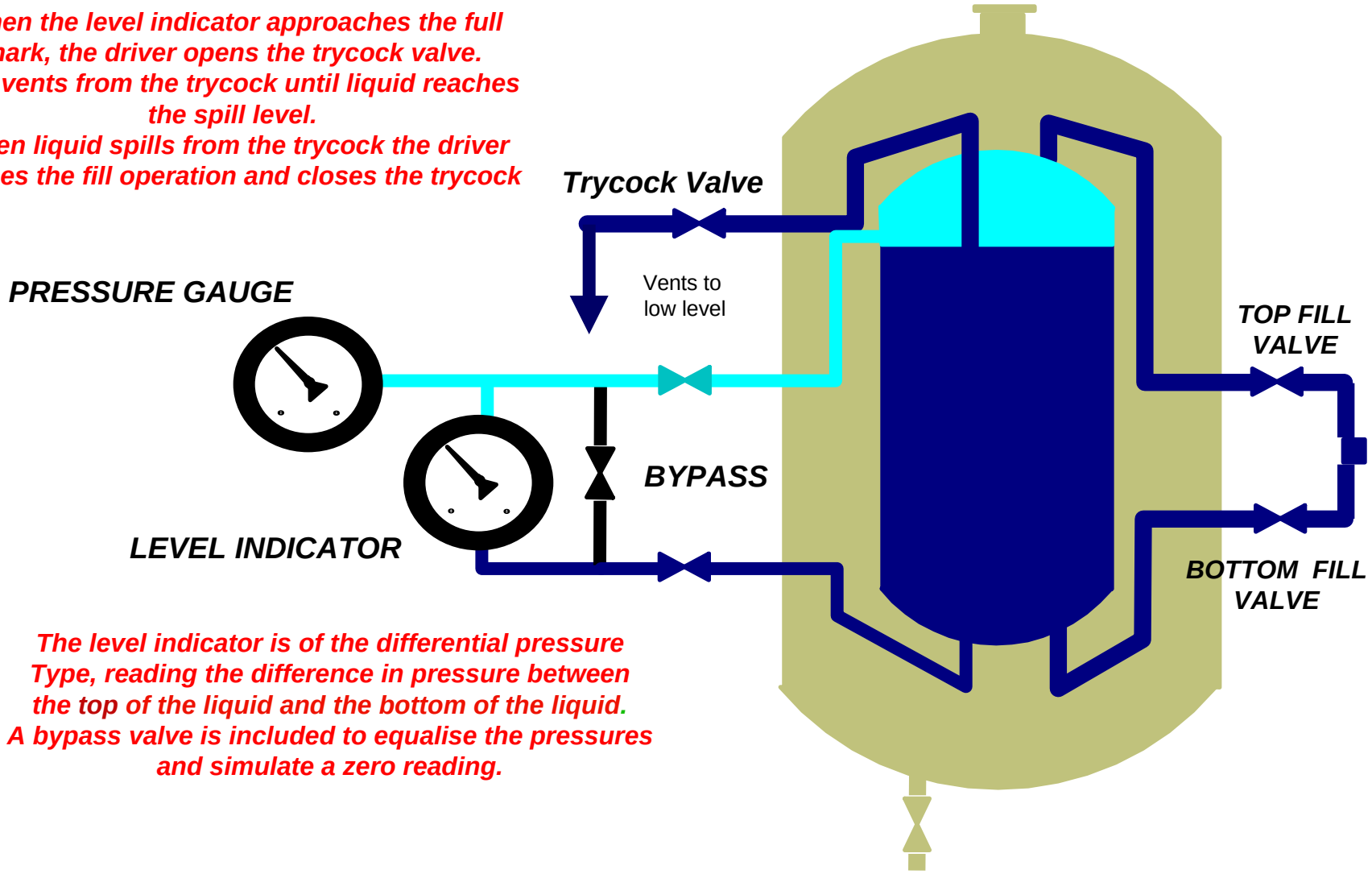
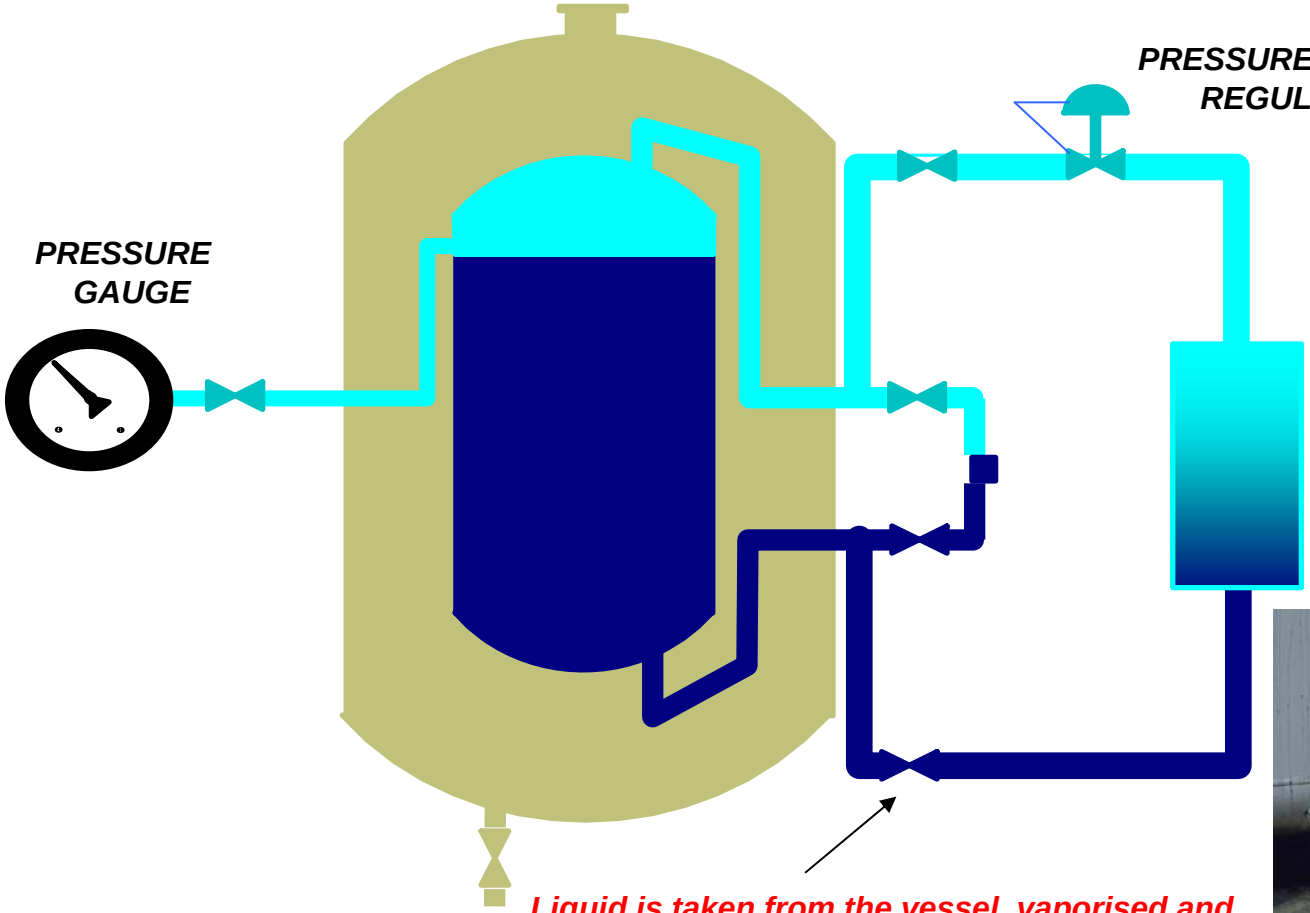
When the level indicator approaches the full mark, the driver opens the trycock valve. Gas vents from the trycock until liquid reaches the spill level.
When liquid spills from the trycock the driver ceases the fill operation and closes the trycock



The level indicator is of the differential pressure Type, reading the difference in pressure between the top of the liquid and the bottom of the liquid.
A bypass valve is included to equalise the pressures and simulate a zero reading.

Pressure raising circuit

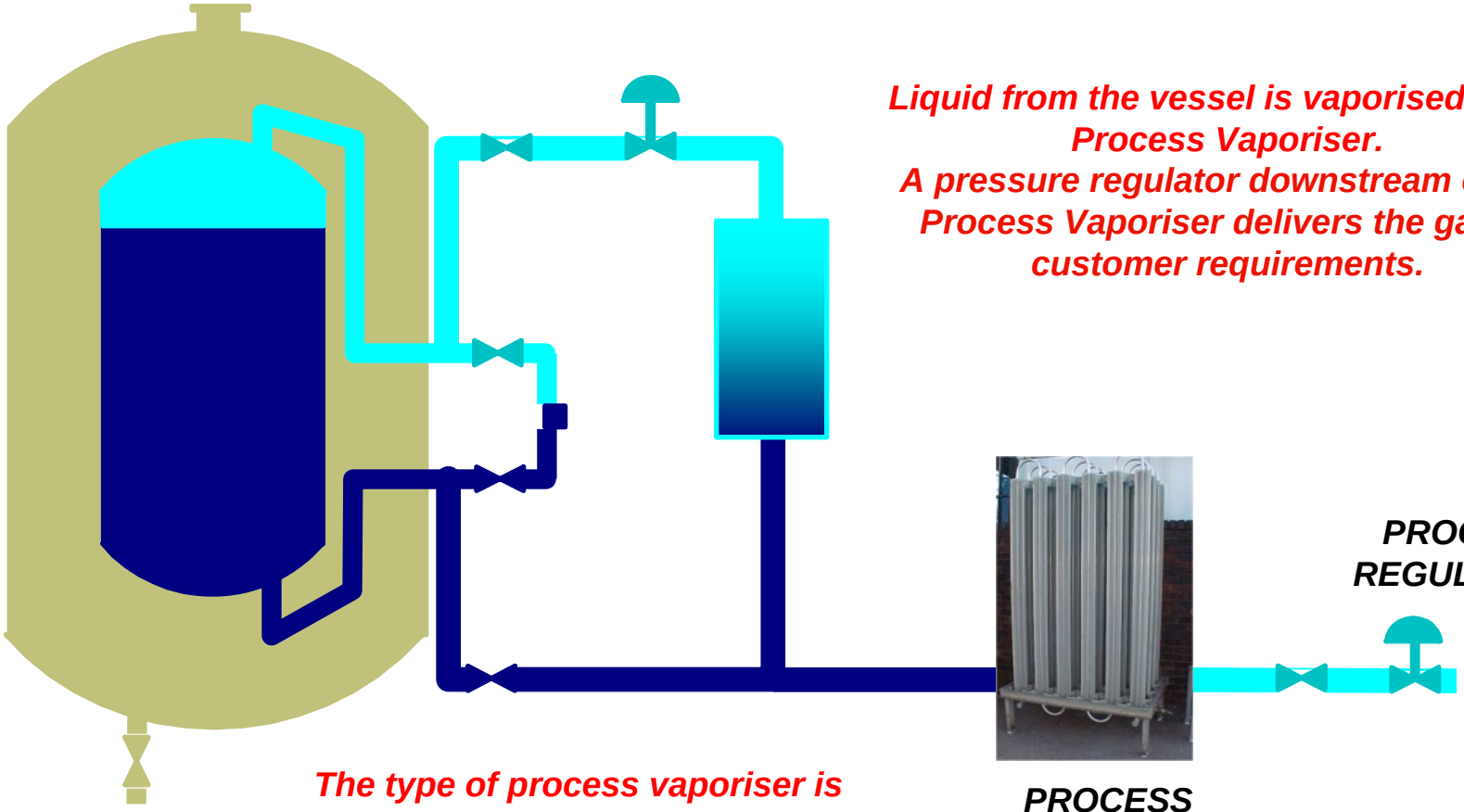
If the customer use is large, the drop in liquid level may result in a fall in pressure in the vessel,
The pressure raising circuit is design to maintain the set operating pressure



The pressure is controlled automatically by the Pressure Raising Regulator which can be pre-set to the Customer's required pressure.

Liquid is taken from the vessel, vaporised and returned to the top gas space to maintain the vessel pressure.

Vaporisation - to convert the liquid to gas



Liquid from the vessel is vaporised in the Process Vaporiser.
A pressure regulator downstream of the Process Vaporiser delivers the gas to customer requirements.

PROCESS REGULATION

PROCESS VAPORISER

The type of process vaporiser is dependent on:
- *the required flow rate*
- *the customer's site services*
- *the space available for installation*

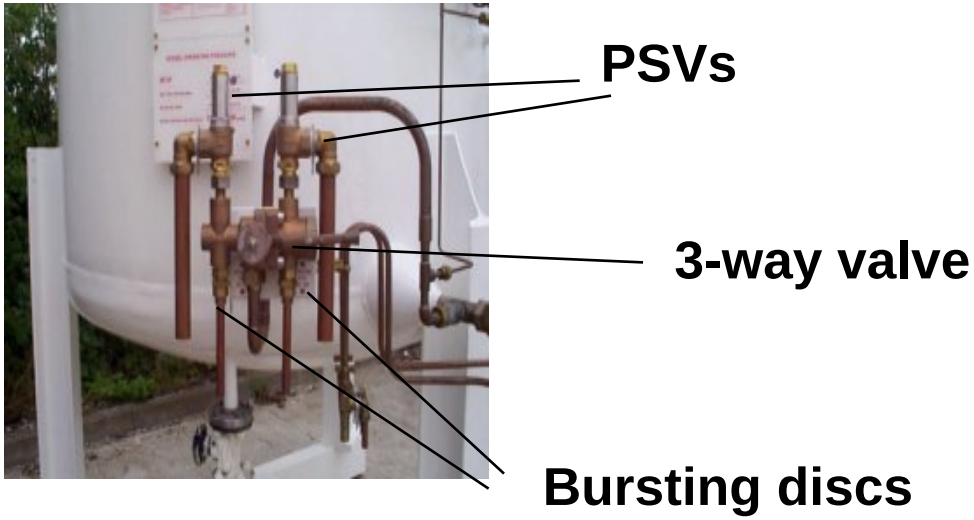
Over pressure protection

Under normal operation excess vessel pressure will not be an issue. However, if the product is not used for an extended period or there is an issue with the vacuum, the heat in-leak may cause the liquid to warm, resulting in an increase in boil-off and a pressure rise in the vessel.

The vessel is equipped with a duty and standby set of pressure relief devices. The system has a pressure safety valve and a bursting disc on each side of the 3-way valve sized to cope with the boil-off rates likely to be experienced under fault conditions.

The 3-way valve allows one set of devices to be 'on line' and one set isolated. This allows the relief devices to be maintained without interruption of supply.

The 3-way valve cannot be set to isolate both sides simultaneously.



Automatic Economisation

Some vessels are designed with automatic economisation so that if the vessel pressure rises through low or intermittent use, any potential boil-off gas is fed into the process line in preference to liquid.

Typical economiser systems are shown on a following slide but in brief they use a regulator to sense the higher than normal pressure and allow this gas to be fed to the liquid outlet line until the gas pressure drops to normal.

Designs vary but in all cases this does result in some pipework being subjected to thermal expansion and contraction on each operation of the economiser.

- The high pressure gas can either be returned to the liquid line at ambient temperature (hot piped) or at low cryogenic temperatures(cold piped) depending on the design.
- Hot piped systems experience greater thermal expansion than cold piped systems
- Large tanks have longer associated pipework, which results in greater thermal expansion

Automatic Economisation

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The vast majority of BOC vessels do not have any automatic economiser systems and are not susceptible to fatigue stresses from thermal cycling.

Within the BOC organisation, of those vessels that do have the facility, they are in the main small vessels in the cold-piped configuration.

These have been confirmed as being acceptable for continued operation

There are a small number of vessels in operation in BOC that are large and hot-piped. The economiser circuits on these have already been isolated to prevent thermal stresses occurring.

Piping arrangements for typical Hot and Cold arrangements

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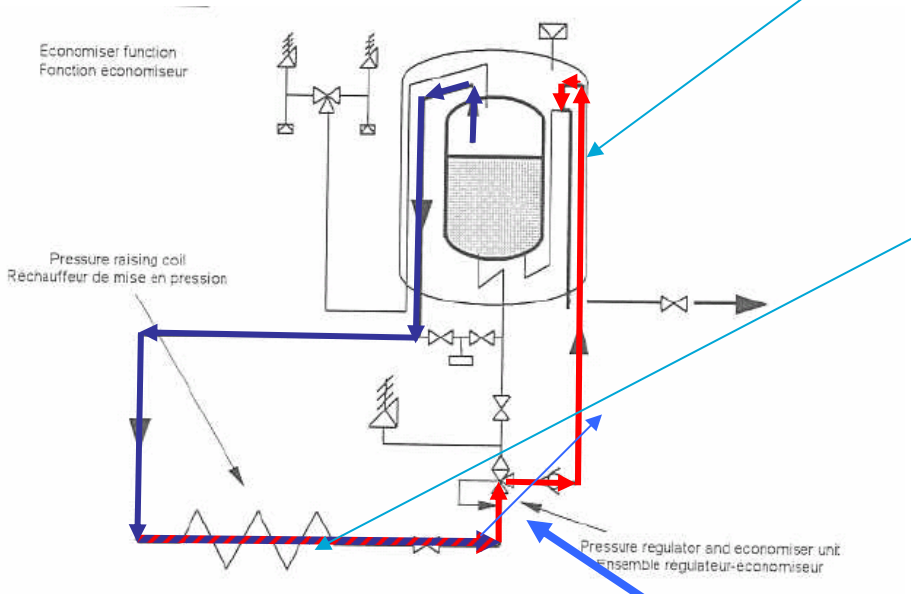
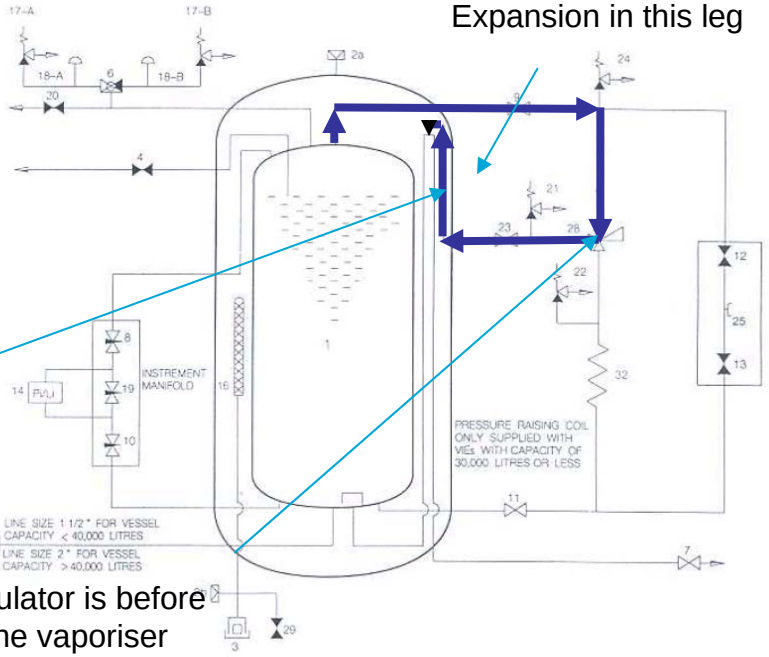
High thermal expansion in this leg



Hot piped gas passes through a pressure raising vaporiser before going back into the interspace and so is at ambient temperature

Low thermal Expansion in this leg

Regulator is after the vaporiser



Cold piped gas diverts back to the interspace without passing through the vaporiser and so is cold

Regulator is before the vaporiser

Failure mode

High thermal expansion in this PIPE can, under certain design and operational conditions, result in high stress on the WELD resulting in failure

The leak that results if not attended to quickly can result in further pipework damage and significant leakage

This in turn can embrittle the outer shell and cause premature failure as shown

Indications/conditions that would be visible in the event of an internal pipework leak

Ice patches on the side of the outer jacket

If there is an internal leakage of liquid the ice patch will be significant in size

There are occasions when ice patches are not indicative of a leak. They may be due to voids in the perlite insulation or simple vacuum loss through poor seals.

However, all ice patches should be reported to BOC or the tank owner for investigation and remedial action

An ice patch combined with a plume of condensation from the tank interspace over the pressure-relief port/bursting disc is indicative of an internal leak

Immediate action is required

Contact BOC or the tank owner immediately; the vessel will have to be depressurised and emptied

Comparison of visible conditions between internal leak and simple loss of vacuum

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Conditions that would indicate an internal leak	Conditions that would indicate other interspace issues such as simple loss of vacuum or insulation slippage
Excessive icing over an extensive area of the outer shell that appears suddenly and rapidly expands	Outer shell moist on dry days
Venting of cold gas/liquid from either the interspace relief port or bursting disc	Continual problems, with storage tank operating pressure being high and pressure safety valves lifting
	Small ice patches in localised area that do not spread quickly
	Algae growth on the outer shell on vessels in open areas (algae may grow naturally on vessels in the shade/under trees etc)

If in any doubt report it to BOC or the tank owner

General housekeeping issues

For the continued safe operation of the tank, it is imperative that the site operator/tank user maintains a close watch on the installation to ensure that any incorrect conditions are acted upon and rectified as soon as possible. It is recommended that a daily inspection is undertaken by a trained operative and a log of the conditions maintained. This can be useful in any investigations in the future and enables trends to be highlighted in parameters such as pressure and usage.

As well as the physical condition of the tank, the maintenance of the prescribed safety distances is a priority. These vary with product and size of vessel and are detailed in the following technical data sheets.

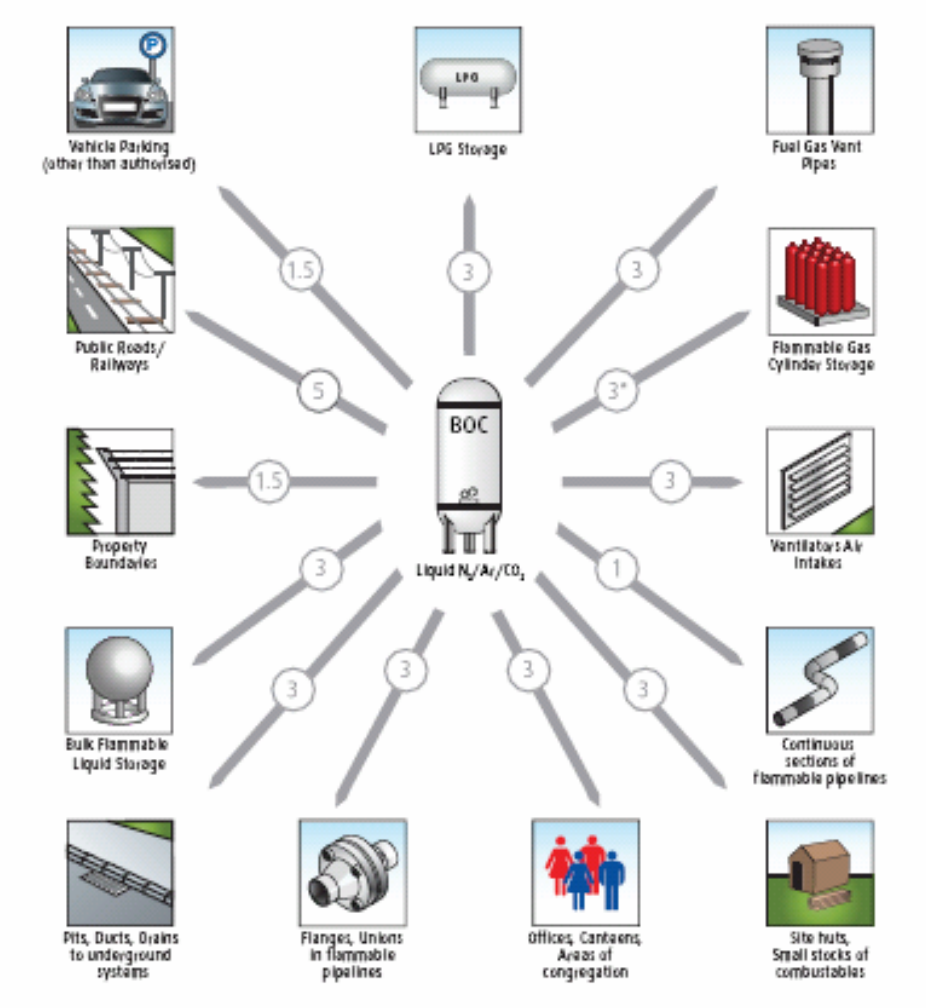
As well as maintaining the separation distances, it is imperative that access is maintained at all time to allow:

Delivery vehicle access

Emergency Services vehicle access

If access is restricted it may result in an aborted delivery and subsequent loss of supply

Nitrogen safety distances



Safety distances for liquid nitrogen, argon or carbon dioxide storage, 1000 to 250,000 litres net liquid capacity. Technical data.

Oxygen safety distances

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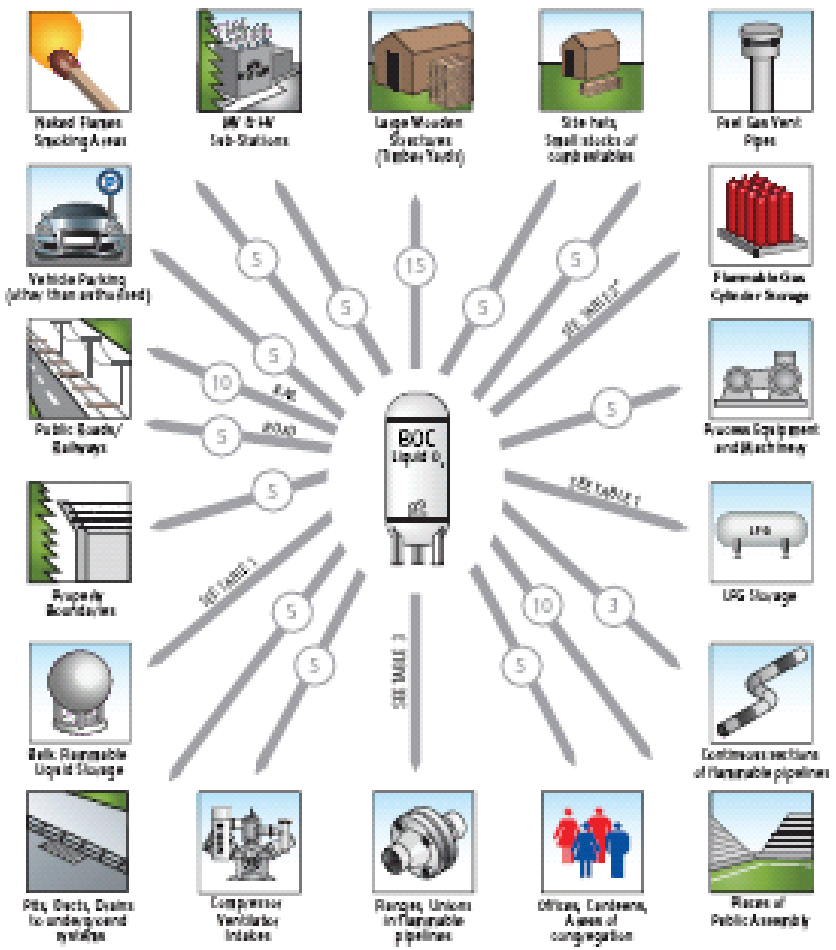
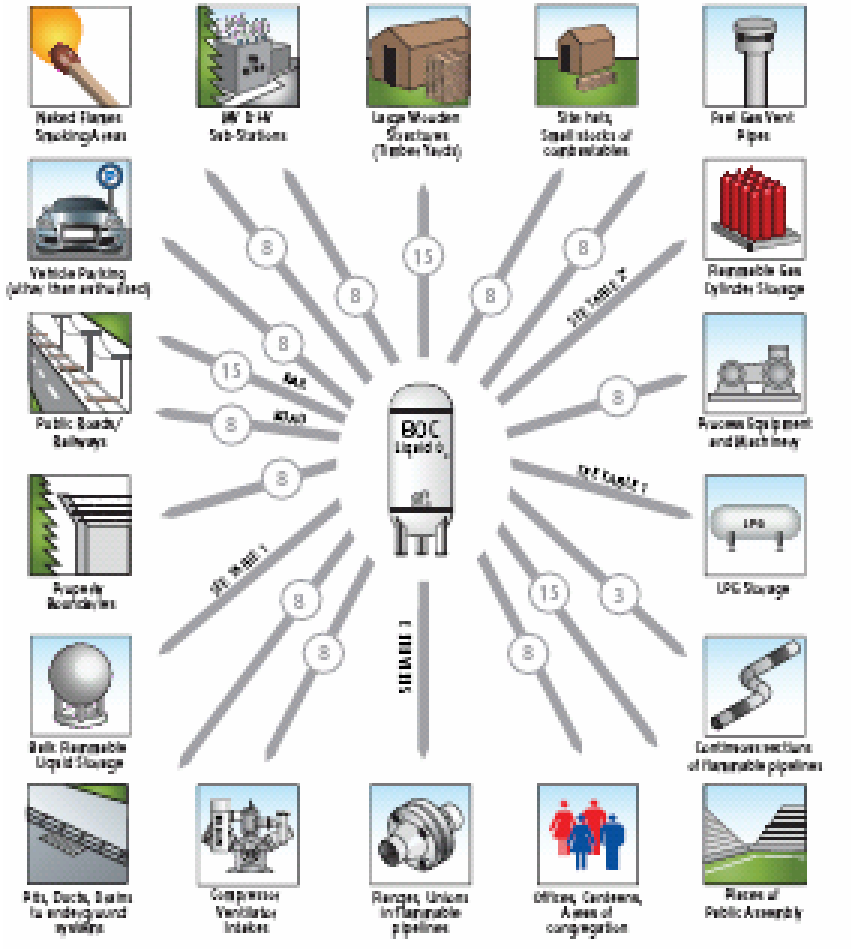


Safety distances for liquid oxygen storage, 1000 to 17,500 litres nett liquid capacity. Technical data.



Safety distances for liquid oxygen storage, 17,500 to 175,000 litres nett liquid capacity. Technical data.

Housekeeping .....daily checks

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Visual inspection of the installation

- Confirm no mechanical damage is visible
- No abnormal frosting/ice patches on outer shell
- No visual/audible leaks from any part of the system
- No obvious changes in the visual appearance such as excessive icing on the vaporiser

  If the system has a changeover facility between sets of vaporisers, confirm this is operational

  Details on ice build up and operational mode are in the user manual for each system

  Pipework downstream of vaporisers should not be iced or frosted
- Fenced compound is free of any stored materials that are not part of the gas storage system especially flammable materials
- Adequate liquid level is available for the expected use
- Pressure is within normal operating tolerances (check against vessel data plate value).

Housekeeping ....daily checks

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–Check all valves are in the normal operating positions

- This should include actuated valves if fitted

–If any electrical items form part of the system check

- All panels are "on"
- There are no alarms displaying on the panel interface units
- The panels and wiring are in good condition

–Confirm the fencing and gates are in good condition and security levels are being maintained

–Confirm all the signs and warning notices are in place and clearly visible

–Confirm that any lighting to allow operation such as deliveries during hours of darkness is working and in good order.

Note:

After a delivery ensure that the blanking cap is in place on fill coupling and that there are no leaks. This is best done approx one hour after delivery when any ice on valve seats will have thawed

Daily Checklist

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BOC Customer Engineering services

Daily Inspection Check List for Vacuum Insulated Storage Vessels

Step	Check
1	Check vessel outer shell for evidence of ice patches
2	Vessel contents are adequate for expected use.
3	The vessel pressure gauge is indicating pressure and is within the normal operating range.
4	If a Liquid Decant attachment is installed on the vessel: • the filling hose/coupling for wear and tear • the flash gas vent pipe for blockage or obstruction.
5	The vaporisers for excessive ice build up. Reference the Ice Build Up section of this manual for more information. • For ambient vaporisers defrost as necessary.
6	The pipework downstream of the vaporiser for signs of frosting.
7	Control panels show "Supply On".
8	Actuated valve visual indicators (white buttons) show valves are in correct position.
9	That there are no alarms conditions indicated on any control/alarm panels.
10	The complete system and all equipment items for general damage/and deterioration.
11	The complete system and all equipment items installation for leaks.
12	The position of the vessel valves, i.e. open or closed, on the vessel are as per the P&ID plate mounted on the vessel.
13	All maintenance isolation valves are open and all vent valves are closed.
14	Any electrical, water or steam supplies to the equipment are healthy.
15	That all safety notices are in place, legible and not obstructed from view.
16	The vicinity of the installation for anything introduced since last inspection which could affect the safe operation of the system. Consult BOC if doubt exists.
17	That the installation compound is kept clear at all times. Make sure there is nothing that will burn, e.g. paper, cardboard boxes, rags, weed growth.
18	Ensure that the area adjacent to the vessel and the site access route for the BOC delivery tanker are kept clear.
19	Ensure that any lighting provided is in good working order.
20	The site security is suitable and sufficient. Gates and fences in good order

Daily Check list

Summary....HSE L11 leaflet

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1

Check system for damage.

Any sign of damage to the tank or installation shall be reported to the operators responsible person and gas supplier immediately.

2

Relief valves are not continually venting

Relief valves may vent periodically under normal operating conditions. However, if they are venting continually this shall be reported to the operator's responsible person and gas supplier immediately.

Typical tank relief valves

3

Check for abnormal frosting on tank surface

Under normal use frosting and ice will develop around pipes, valves, controls and vaporisers as shown in picture 1 opposite.

The operator should inspect the outer skin of the tank for any new or abnormal signs of frosting.

The frosting indicated in picture 2 opposite is an example of an advanced and serious interspace pipework failure. Abnormal condensation that can't be ascribed to morning frost, dew or weather conditions may appear at the first instance of a failure before heavy localised frosting develops.

If any abnormal frosting is found, it shall immediately be reported to the gas supplier.

Picture 1 | Picture2

✓ ✗

Examples of acceptable and abnormal icing.

Summary…HSE L11 leaflet

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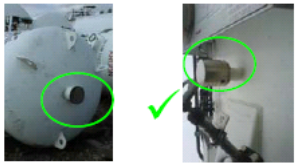
4 **Check gas is not venting from any part of the tank surface or connections to it.**

Vacuum insulated tanks are fitted with a device to prevent the outer jacket being pressurised in the event of a leak from the inner vessel or interspace pipework. The operation of this device may be visible and/or audible as escaping gas from a port or connection on the outside of the tank and is an indication of a serious internal problem with the tank, this must **urgently** be reported to the gas supplier.



Examples of vacuum protection devices

This picture shows gas venting from a vacuum protection device

5 **General condition and security of the system is satisfactory**.

Check area is clear of debris, general housekeeping and security is good and that delivery vehicle access is clear.

NB for liquid oxygen it is essential that the area around the installation is kept clear of all combustible material.

6 **Vessel pressure and contents indication is functioning**

In case of doubt report to the operator's responsible person and gas supplier.

7 **Safety warning signs in place**

Signage should be in good condition, visible and kept up to date.